The VGX will maximize the efficiency of glovebox experiment planning, operations, training, and trouble-shooting for astronauts and support crews, thus greatly reducing the risks associated with Space Station glovebox experiment success. With the realistic simulation environment of the VGX, gravity can be turned on and off, allowing astronauts to practice experiments in a simulated real-time microgravity environment while still on Earth. This represents a significant advancement over current training methods which must be developed and practiced entirely on Earth under its constant unit gravity acceleration.

In a continuing effort to improve the VGX, many new advances in virtual environment computing and technologies are also being developed which push NASA to the forefront in real-time visual/haptic simulation and computing research. The resulting VGX simulation system helps solve NASA's glovebox development and training requirements, but at the same time, it provides a generalized simulation engine for any immersive environment application, such as biomedical/surgical procedures for interactive scientific or engineering applications. For NASA, the Virtual Glovebox can not eliminate the need for training on LSG mock-ups using real experiment equipment and real biological specimens; however, the VGX streamlines these processes and provides astronauts with a means to keep their skills sharp both on Earth and in space. With better ways to engineer, develop, and train for the many complex life science experiments that astronauts will perform onboard the ISS, Ames Research Center is paving the way to successful biological research in space.

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ADVANCED LIFE SUPPORT

## Advanced Life Support Power Reduction

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This research involves modeling of the power and energy usage of regenerative life support systems suitable for exploring the Moon and Mars. System energy integration and energy reuse techniques are being investigated, along with advanced control methods for efficient distribution of power and thermal resources. The high power requirements associated with food production and overall closed regenerative system operation remain a critical technological challenge. Optimization of individual processors alone will not be sufficient to produce an optimized system; system studies must be used in order to improve the overall efficiency of life support systems.

Designs are being developed that match sources of waste heat—crop lighting and solid waste processing systems—with processes that can use this waste heat—water processing, food processing, food preparation, and heating water for showers, for washing dishes, and for washing clothes. Using energy integration techniques, optimal system heat exchange designs are being developed by matching hot and cold streams according to specific design principles. For various designs, the potential savings for power, heating and cooling are being identified and quantified, and estimates are being made of the emplaced mass needed for energy exchange equipment.

Advanced control system designs are also being developed that allow for more efficient distribution of resources, such as system cooling water or electrical power in order to reduce system power requirements. More efficient energy usage can be achieved by allocating power and thermal resources in a dynamic fashion. Advanced control techniques, such as market-based control, can be used in order to smooth out system thermal and power loads. Reductions in peak loading will lead to lower overall requirements. The controller dynamically adjusts the use of system resources by the various subsystems and components in order to achieve the overall system goals. A typical system goal would be the smoothing of power usage and/or heat rejection profiles, while maintaining adequate reserves of food, water, oxygen, etc., and not allowing excessive build-up of waste materials. Initially, computer simulation models are being used to test various control system designs. The most promising of these will be tested using a laboratory-scale, life-support-system testbed at Ames Research Center.

Energy balance models are being developed to support both the energy integration and the dynamic resource allocation work. These models leverage off of existing mass flow models of regenerative life support systems developed at Ames. The heat exchange designs and control schemes developed as part of this NRA research will be provided to Johnson Space Center for use in the development of the ALS Systems Integrated Test Bed (also known as BIO-Plex) and in the design of flight hardware for Moon or Mars missions.

Currently, energy integration techniques are being applied to the life support problem. Several potential designs that would be suitable for various Mars missions have been selected for application of the energy integration analysis. Life support data have been collected, and an optimized heat exchange design has been developed for each scenario. For each design, the potential savings in energy and cooling have been estimated.

In addition to the energy integration work, advanced control system designs are being developed that allow for more efficient distribution of electrical power. A dynamic model of the BIO-Plex air loop has been created and serves as a platform for the development of active power management strategies. Several resource allocation objectives have been defined and tested. One objective that was considered was to reallocate power as needed to the various life support processors to eliminate surges in power usage over time; however, the reallocation of power was subject to constraints. For example, material storage levels needed to be maintained, as well as atmospheric conditions within the life support chambers. This power management system has been demonstrated using the simulation model, and has performed reasonably well. A second objective that has been and continues to be investigated is to smooth the demand for power throughout the system over time.

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